27TH GERMAN CONFERENCE ON ARTIFICIAL INTELLIGENCE (KI2004)
SEPTEMBER 24, 2004
ULM, GERMANY

FIRST INTERNATIONAL WORKSHOP

ON

APPLIED ARTIFICIAL INTELLIGENCE AND LOGISTICS

SPECIAL FOCUS ON MOBILE SOLUTIONS

PROCEEDINGS OF THE KI2004 WORKSHOP
SEPTEMBER 24, 2004

Ingo J. Timm, Holger Wache,
Martin Christof Kindsmüller, Bernd Hellingrath
(Editors)

TZi Center for Computing Technologies

KI 2004

FIRST INTERNATIONAL WORKSHOP ON APPLIED ARTIFICIAL INTELLIGENCE AND LOGISTICS

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SCHEDULE

09:00	**INGO J. TIMM** OPENING REMARKS AND INTRODUCTION
	TECHNICAL SESSION
09:15	**SCHLIEDER AND STEIN** RECOGNITION OF INTENTIONAL BEHAVIOUR IN SPATIAL PARTONOMIES
09:40	**LANGER AND TIMM** DISTRIBUTED KNOWLEDGE MANAGEMENT IN THE TRANSPORTATION DOMAIN
10:05	**SCHOLZ-REITER ET AL.** STRATEGIES OF SOCIAL INSECTS AND BIOINSPIRED CONCEPTS IN LOGISTICS – STATE OF THE ART AND NEW PERSPECTIVES
10:30	**COFFEE BREAK**
	PANEL DISCUSSION
11:00	**WACHE** TERMINOLOGY INTEGRATION FOR THE MANAGEMENT OF DISTRIBUTED INFORMATION RESOURCES
11:15	**NIMIS** THE AGENT.ENTERPRISE MULTI-MULTI-AGENT SYSTEM
11:30	**KENN** WEARIT@WORK - EMPOWERING THE MOBILE WORKER BY WEARABLE COMPUTING
11:45	STATEMENT OF INTERESTS OF THE PARTICIPANTS
12:15	FUTURE DIRECTIONS AND FURTHER STEPS
12:45	**INGO J. TIMM** CLOSING REMARKS
13:00	**END OF WORKSHOP**

PREFACE

Since the last decade, management trends as just-in-time, or shortened time-to-market and a more flexible consideration of customer' demands are leading to a rapid change of market requirements cooperative relationships in logistic networks. In distributed logistics the knowledge about products, production processes, and distribution are becoming critical factors in the value added chain. Focusing on a single enterprise this leads to an integration of AI into business information systems. In computer-mediated collaboration, new approaches must enable the interaction of distributed systems and the information exchange in an ad-hoc manner e.g. on the basis of explicit semantic descriptions of data. To face this task application of mobile and wearable system solution is in question, if conventional approaches or process implementations are not adequate ergonomically, technically or economically. In the domain of logistics, mobile computing could serve as an innovative technique to enable a paradigm shift to more autonomous logistic processes. In combination with artificial intelligence techniques, complex interacting logistic applications on the basis of explicit knowledge representation and highly distributed inference processes can be realized.

The accepted and invited papers will discuss the following aspects:

- Mobile and wearable assistive systems for logistics using artificial intelligence techniques
- Ambient intelligence, ubiquitous and pervasive computing supporting logistical processes
- Context awareness and intelligent information representation
- AI methods for the realization of the paradigm of a "casual" human-computer interaction and for user modelling
- Scalable and/or distributed solutions for (mobile) knowledge management and (mobile) information retrieval
- Ontologies and/or modern approaches of intelligent information exchange in a supply-chain context
- Theoretical and methodological approaches to application of DAI (e.g. multiagent systems) in logistics
- Identification, modelling, simulation, and formal representation of real-world business scenarios in logistics
- Further improvements of AI techniques in the context of well-defined problems of the logistic domain
- Reference architectures and re-use of AI techniques
- Mutual influences of evolving business standards, e.g., RDFS, OWL, and XML, and their fruitful merging with existing agent technology standards and or AI techniques

Three papers have been accepted for presentation and there are three invited papers. The workshop will start with the technical session and after a short coffee break, three key notes on "Mobile Computing", "Artificial Intelligence" and "Logistics" will open the panel discussion.

Ingo J. Timm, Holger Wache,
Martin Christof Kindsmüller, Bernd Hellingrath
Ulm, September 24th, 2004

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TECHNICAL PAPERS

TZi Center for Computing Technologies

KI 2004

Recognition of Intentional Behaviors in Spatial Partonomies

Klaus Stein and **Christoph Schlieder**[1]

1 Introduction

Information services designed for use on handset devices such as smart cellular phones or GPS-equipped PDAs exploit knowledge about the user's location to decide what type of information to present. Typical examples are location-aware information systems for museums (see [1, 2]) or computer-mediated outdoor games (see [4, 3]). In cases where the user's current location does not provide sufficient context, the history of locations visited by the user provides an additional source of information. This is especially helpful when user behavior is interpreted with respect to regions of interest within which only certain types of behavior need to be discriminated, e.g. crossing the region vs. visiting the region.

Consider the motion pattern recorded with a GPS receiver shown in fig. 1. It is the trace of a player of CityPoker, a game we devised to study space-related decision processes. The game involves two players (or teams) that move by bicycle around the historical center of Bamberg, Germany. Each player is dealt a hand of five cards which he can improve by finding cards that are hidden in town. Hiding places are specified by noisy coordinates with the consequence that at certain moments players are involved in search phases while in others they chase for reaching a place before the opponent. Regions of interest are for instance the neighborhoods of places where cards could be hidden such as regions *A*, *B* or *C* in fig. 1. An computational analysis of the motion pattern should reveal that the player had the intention to cross region *C* while in region *A* and *B* he had the intention to search for a card.

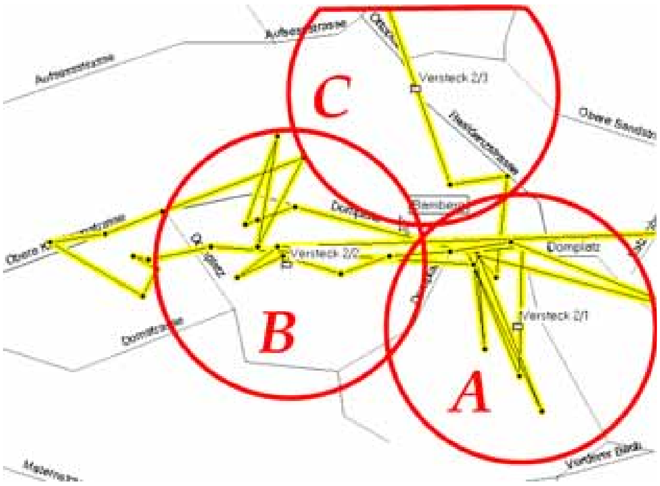

Figure 1. Spatio-thematic regions in the game of CityPoker

2 Moving in Partonomies

Designing a mobile information device that supports an outdoor game such as CityPoker is challenging because the possibilities of the user to directly interact with the system are severely limited. This is especially true for the chase phases of the game when players ride a bicycle at high speed. The task of motion pattern analysis consists in determining whether or not a user located in a region will need information associated with that region. If the player's intention is to search the region a detailed map of the region will be helpful while no change of presentation mode is desirable when the player intends to just cross the region.

Although the number of user intentions is virtually unlimited, generally, only few types of intentions need to be discriminated in order to determine the user's information needs. Schlieder and Werner [6] exploit this fact by proposing not to directly map spatial behavior onto information services but instead use intentions as an intermediate level of modeling (Fig. 2). They describe an architecture for interpreting motion patterns in terms of user intentions in the context of a mobile tourist information system. The approach is characterized by two assumptions which we assume to be valid for the analysis presented in this paper, the behavioral specificity assumption and the partonomic segmentation assumption.

The *behavioral specificity assumption* expresses a basic intuition of activity-based spatial ontologies, namely that all spatial entities are defined by the actions which can be performed upon them (see e. g. [5]). In particular, spatial regions are defined by the set of activities that may occur in them. For our purposes, a region's boundary delimits the area within which

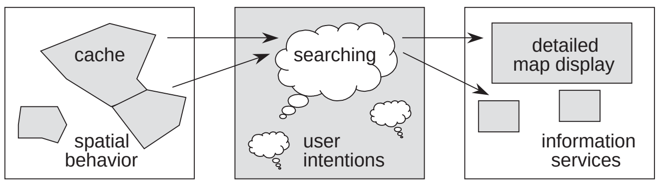

Figure 2. Intentions as an intermediate level in modeling behavior-service mappings

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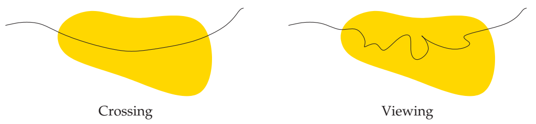

Figure 3. Examples of motion track patterns.

a motion pattern can be meaningfully interpreted as the effect of a particular type of user intention such as searching around a place where cards are hidden in CityPoker. We call regions defined by a set of user intentions spatio-thematic regions.

Intentional spatial behavior occurs at different levels of granularity. Longer lasting intentions are often associated with large parts of geographic space while intentions which are subject to frequent change may be restricted to regions that appear almost point-like within the precision range of location measurement. As a consequence, spatio-thematic regions corresponding to specific intentions will be contained in spatio-thematic regions corresponding to more general intentions resulting in a hierarchical organization, i.e. a partonomy of regions.

In order to simplify the description, we restrict our attention to partonomies without overlapping regions in the following. The partonomic segmentation assumption states that the best way to segment the motion pattern is to cut it up into segments at exactly those points where it enters or leaves a spatio-thematic region.

3 Motion Track Analysis

We will now turn to the problem of interpreting a segmented motion pattern. Fig. 3 shows two different motion patterns within a given spatial region, a smooth track with fairly high speed (left) and a rather winding track (right). While their main shape (in large scale) is similar their micro structure differs. Thus different intentions can be distinguished by different motion patterns.

3.1 Motion Track Structure

To distinguish different intentional behaviors the focus is *not* on the gross shape of the motion track but on its micro structure. The gross shape tells us, which roads/corridors/etc the person traveled but not *why*. It certainly helps constricting the variety of possible intensions but is not sufficient on its own. Thence for classifying motion shapes we additionally want to single out its micro structure. As described in [7, chapter 12] this can be done with aid of classical corridor based line generalization algorithms by calculating the ε-histogram giving the characteristics of the serratedness over all resolution levels.

Fig. 4 shows that the ε-histograms a and b of two given motion tracks A and B reveal information about their micro structure.

3.2 Velocity

The motion track of a person calling on a special point of interest, e. g. a telefon box will show a rapid decrease of speed at this point (reaching it), some time of standstill and an increase of speed afterwards (leaving it). On the first view this seems

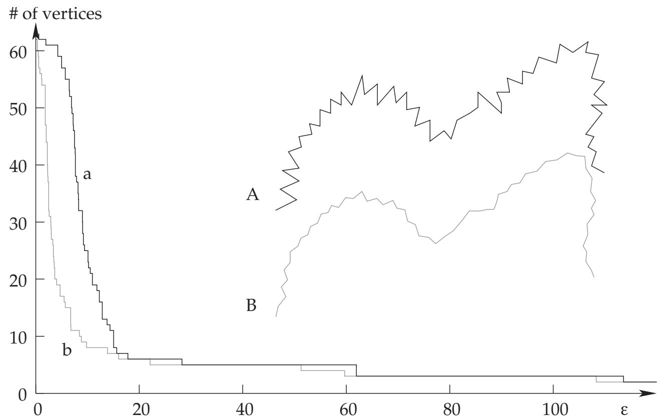

Figure 4. ε-histograms of two motion tracks A and B

to work fine for intentional behavior identification, but single standstills can be caused by very different reasons: stopping at the traffic lights, tying the shoes, being asked for the station by a tourist, resting, watching a placard, ...

So simple standstills do not reveal the intention of the observed person but velocity patterns can. The motion track of someone walking down a long street stopping in front of any third showcase watching the new model railways, shoe fashion, clothes and fishing rods may nearly show a straight line, but the velocity curve will show the characteristic pattern of stop and go (which will be different from the stop-and-go pattern of a car in the traffic jam).[2]

Therefore the consideration of the velocity curve gives additional decision criteria for intentional behavior determination.

3.3 Classification of Motion Patterns

Using the elaborated measures the track data can now be classified. One advantage of the partonomic approach is that the possible regions of interest are predefined and therefore the possible intentions within a region are limited.[3] So for each region R a set of possible intentions $\mathbf{I}_R = \{I_1, I_2, \ldots, I_n\}$ can be predefined from which one is selected regarding to the given motion track p, using its micro structure as well as the main shape and velocity with simple rules like

$$\overline{v} > 10\frac{\text{km}}{\text{h}} \quad \Longrightarrow \quad \text{running}.$$

or prototype based (fuzzy) matching.

3.4 Bringing the Parts together

Given a partonomic structure $\mathbf{P}$ on a certain space a person moving within this space incrementally enters and leaves regions $A, B, C, \ldots \in \mathbf{P}$. Figure 5 shows such a walk (motion track p): the person enters F, leaves F, enters G, leaves G, enters D and so on, giving the sequence

$$-F - G - D - C(A - B-) - G - .$$

[2] Additionaly velocity shows up in the ε-histogram.

[3] Certainly there will be some few people with very different intentions to anything the system designer could imagine, but this cases are rare and unavoidable.

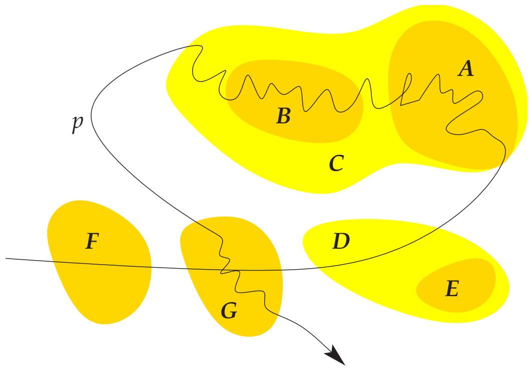

Figure 5. Moving through a partonomic structured space

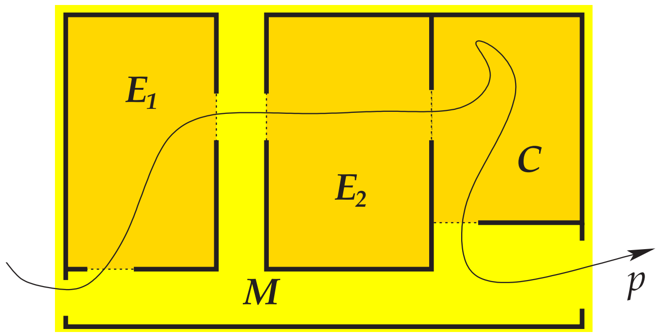

Figure 6. Visiting a Museum?

As stated above for each region R a set of possible intentions $\mathbf{I}_R$ is predefined and a set of rules/prototypes is given to identify the present intention. This is done by selecting the part p_R of p inside R (by splitting p at the point, where the motion track enters and where it leaves R).

Regarding region F the matching is simple: the measures (ε-histogram, velocity curve, main shape, ...) of the part p_F of p inside F are calculated and the rules/prototypes specifying the different intentions I_1, I_2, ... are applied to them. If one rule set matches (in case of prototypes: the similarity is close enough), the corresponding intention I_k is selected. If nothing matches the intention within F is unknown. The same procedure is valid for the regions D and G. Even though there is a region $E \subset D$, E is not crossed by p and therefore savely ignored.

The fact of G being crossed two times by p does not lead to any trouble because of the chronological order. The two events are temporally seperated and there is no conflict in processing a motion track showing one behavior in the first and another behavior in the second visit (we get parts p_{G1} and p_{G2} of p).

Within region C things become more sophisticated. Here p first enters C and within C crosses A and B before leaving C again and now the hierachical structure of $\mathbf{P}$ is used. In our example the part p_C of p inside C is cut in four segments p_A (part of p inside A), p_{AB} (part between A and B), p_B (part inside B) and p_{B0} (part between B and the border of C), we get

$$p_C = p_A \circ p_{AB} \circ p_B \circ p_{B0}.$$

On the first step the behavior within A and B is processed, revealing the intentions I_A and I_B, we get the mixed representation

$$r_C = I_A \circ p_{AB} \circ I_B \circ p_{B0}.$$

(If no intention I_B is found, because no rule set matches, the intention set $\mathbf{I}_B$ is ignored and we get the sequence

$$r_C = I_A \circ p_{A0} \quad \text{with} \quad p_{A0} = p_{AB} \circ p_B \circ p_{B0}\,,$$

likewise for region A).

For processing r_C the rule set for $\mathbf{I}_C$ is enhanced. The parts p_{AB} and p_{B0} can be handled with rules as described in section 3.3, but additionally the knowledge about the intentions I_A and I_B can be incorporated.

Figure 6 gives an example. Here we have a museum M with two exibition rooms E_1 and E_2 and a cafeteria C. The motion track p gives the sequence

$$-M(-E_1 - E_2C-)-.$$

To analyze the intention of the observed person within M the intentions found by analyzing the track within E_1, E_2 and C can be used: if I_{E_1} and I_{E_2} are "crossing" and I_C is "resting" we can conclude that I_M is "visiting the cafeteria" and not "visiting the museum".

Certainly the partonomic hierarchy can be deeper, the museum is part of a town and so on, and on each step (each region) the intentions found in the enclosed regions are used.

3.5 Incremental Processing

The procedure given so far incrementally processes a given motion track. A region R is entered and after leaving it, the behavior within it is analized and the corresponding intention I_R is selected. In practice this is to slow. To build a guide and assistance system giving contextual information to its user the system has to know the intention of the user when he or she *enters* or at least when she or he is inside a certain region and not when he or she is done. This gives the following demands:

1. the rule sets are able to work on incomplete data,[4]
2. the motion track measures are calculated (and recalculated) on the fly,
3. the assumptions about the user's intention within the current region can be revised by ensuing motion data.

After a region R is left, the intention I_R is fixed and will not longer change.

4 Conclusion and Outlook

This paper describes the basic steps of the incremental processing of motion tracks through partonomic structured environments from the calculation of different measures on the low-level geometric structures to the application of rule sets for intention detection and mixed-mode representations on higher levels.

[4] e. g. by different rule sets for the incremental and the final processing. For example it may be useful to assume that someone entering a museum and walking slowly is visiting the exibition as long as no further data is available even if the final rule set for "exibition visit" has more and stricter rules.

The next important step towards a full featured motion based partonomic intention detection system is the development of a model language for the description and application of complex rule sets.

Additionally, the restriction of intention dectection to the part of the motion track within the current region can be relaxed and the history of the motion track taken into account. Furthermore, overlapping regions should be allowed and properly handled for the modelling of real world scenarios. And last, but not least the framework should be able to handle dynamic partonomies: the change of regions during the motion, e. g. the aside-region in a soccer-game is changing all the time (and certainly is an important region for the players and the referee).

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Distributed Knowledge Management in the Transportation Domain

Extended Abstract

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A Paradigm Shift and its Limitations”
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1 Introduction

For a long time, most research on computational modeling of transportation processes has put a strong emphasis on the flow of goods, often based on simplified mathematical problem formulations (e.g. Traveling Salesman Problem, Pick-up-and-Delivery Problem), and, hence, neglecting the increasing importance of knowledge as a resource in real-world transportation problems [1]. In real-world applications, shortcomings of existing planning and scheduling systems are handled rather implicitly by knowledge and experience of the human users involved in the processes.

Since the early nineties, multiagent systems and Intelligent Agents are of increasing concern within software engineering of large scale distributed systems, and have become a leading edge technology. Agent technology seems to be a promising approach if applied to the transportation domain. Supporting the management and integration of planning, scheduling, and controlling processes they can be used as "enterprise delegates" [2].

Various research projects on multiagent transport scheduling have been conducted during the nineties. TELETRUCK and its ancestor projects at the DFKI as one of the main contributors in this research area have investigated different technological aspects, e.g. holonic approaches and auctions [3]. A survey on agent-based approaches to transport logistics has been conducted by Davidsson et al. [4]. On the one hand, the authors come to the conclusion that agents are an adequate means for the transportation domain and have had a significant impact on the state-of-the-art of traffic management research [4, p. 20]. On the other hand, they point out that relevant applications in the real-world and sufficient evaluation are still missing and that agent-based approaches are not addressing strategic decision making, yet [4, p. 20].

2 Autonomous Cooperating Logistic Processes

In 2004, a new Collaborative Research Centre (CRC 637) on "Autonomous Cooperating Logistic Processes – A Paradigm Shift and its Limitations" has been founded at University of Bremen and is funded by the Deutsche Forschungsgemeinschaft. It focuses on adaptive logistic processes including autonomous capabilities for the decentralized coordination of autonomous logistic objects in heterarchical structures. The autonomy of the logistic object such as cargo, transit equipment, and transportation systems can be implemented by novel communication technologies such as radio frequency identification (RFID) and wireless communication networks. These and others permit and require new control strategies and autonomous decentralized control systems for logistics processes. In the setting, aspects like flexibility, adaptivity, reactivity to dynamically changing external influences while maintaining the global goals are of central interest. The underlying logistic models include transportation as well as manufacturing logistics.

In a standard approach to logistics, local entities are making decisions on the basis of pre-defined sets of rules, short-term objectives of the enterprise, and current information about their environment. Strategic objectives of an enterprise are not considered within this kind of local decision making. The innovative approach of autonomous logistic processes involves even transferring of strategic objectives in decision making to local interacting entities. Thus, the local entities have to integrate strategic and short-term objectives. This leads to a strong need of knowledge within the local decision making process.

3 Distributed Knowledge Management

Knowledge-intensive autonomous logistic processes are based on actors with individual properties, facilities, capabilities, and interests. Both actors and environment are constantly subject to change. In consequence, it is impossible to implement systems, which are using perfect information about the environment and the actors have to deal with uncertainty, incomplete, or wrong information. Due to the heterogeneous structure of supply webs, the actors are assumed to be self-interested. Thus, actors do not necessarily share goals nor are they actively participating on global optimization. Nevertheless, it can be beneficial for actors to form groups or teams, temporarily, for individual profit maximization. Actors are in need of deliberation, planning, and plan recognition capabilities, if they are required to make decisions under short-term and strategic constraints within a dynamic and competitive environment.

To meet these requirements for actors within autonomous logistic processes, agent technology seems to be a promising approach. However, as reported in [4], current approaches of agent technology in the transportation domain are not dealing with strategic or knowledge-intensive environments, sufficiently.

Our approach[1] aims at integrating agent technologies and knowledge management approaches to ensure robust and efficient planning and scheduling in the transportation domain. We are introducing an abstract architecture (cf. Figure 1), which is integrating knowledge management within and among enterprises on the basis of local interacting entities. The methodological integration is using web services, intelligent web-services, and Intelligent Agents for implementing infrastructure services like negotiation, machine learning, context management, intelligent information integration, and semantic mediation.

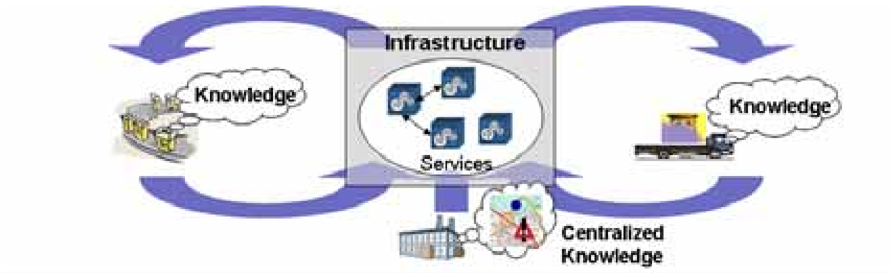

Figure 1. Distributed Knowledge Management

1 The project "Knowledge Management Supporting Autonomous Logistic Processes" is funded within the CRC 637 from 2004-2007.

Acknowledgement

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Strategies of Social Insects and Other Bio-Inspired Algorithms for Logistics: State of the Art and New Perspectives

Abstract

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1 Introduction

The rising demand on current logistic applications results in needs for increasing functionalities and complexity of todays software solutions. The ever-changing conditions of todays markets have considerable influences on planning and control of logistics processes. Because of the increase of relative scarcity of logistic infrastructure combined with the increasing quantity of processes in the value chain in more and more spatially and organizational distributed networks, complex and often contrary requirements for logistic planning and control systems arise. Logistics, i.e. production as well as transport logistics, has to deal with intrinsic structural complexity emerging from both the number of interacting entities including their interdependencies and the virtually infinite number of logistic items.
The majority of currently used production planning and control systems as well as transport management systems are based on centralized optimization procedures. Their successful application in the sketched dynamic environment is often not feasible because such conventional system can not cope properly with disturbances and uncertainties and even suffer from insufficient scalability. To overcome the problems of centralized architectures a number of far reaching new conceptual frameworks for distributed control in the area of manufacturing (including production logistics) have been proposed during the last decade, presenting similar concepts but with different origins. This includes the fractal

factory concept, which focuses mainly on an assumed self-similarity of organizational units, the Bionic Manufacturing System (BMS), which emphasizes biological evolution principles for dealing with dynamic changes or the Holonic Manufacturing System (HMS). The latter approach identifies key elements of manufacturing, such as machines, factories, parts, products or operators etc. with so called holons, which should have autonomous and cooperative properties. With this identification it compares closely to the main ideas of distributed artificial intelligence (DAI), especially the multi agent systems (MAS) paradigm.

2 Multi-Agent Systems in Logistics

At a glance logistics has the objective to transport materials or goods from one place to another, where a demand for these specific goods must be satisfied. This main objective is subjected to several process related constraints as e.g. time windows for delivery, special sequencing demands etc. Furthermore, usually alternative means of transportation are available and at the same time the resources are constrained. Thus, a number of decisions regarding routing and scheduling tasks have to be made under time constraints and uncertain or incomplete knowledge. These characteristics applies both to logistics in production environments (shop floors and production networks of connected production facilities or plants) and transport logistics in general.
Many authors have mentioned that such problems in logistics are a well suited application area for multi-agent technologies. By nature, logistic systems are modular, these systems can be physically decomposed into separated entities like production facilities, machines, operators, orders, packets and pallets, conveyors, parts, sub-assemblies, products, etc. Logistic items are spatially distributed and logistic systems have a decentralized structure. Additionally, the main objective of logistic processes requires the coordination of various logistic items and the allocation of scarce resources. Thus cooperative appendages and communication are prerequisites in successful logistic operations. These prerequisites are congruent with the requirements for promising application of MAS.

3 Using Swarm Intelligence and Ant-Like Agents

A number of known applications of agent technologies in logistics uses intelligent agents with a relatively complicated architecture [1].
In contrast we will explore the usage of a large number of individually simple agents. Because of the layout of logistic systems it is preferable to choose a concept with a high number of agents with limited capabilities than a setup with a few highly intelligent agents.
One main question is how the communication between the elements is performed. In biological inspired artificial intelligence (AI) concepts like the swarm intelligence approach, where the behavior of social insects like ants or bees is copied, communication is carried out exclusively through the environment [2].

Stigmergy depicts indirect communication and coordination within a dissipative field through asynchronous information exchange between agents. Such a coordination mechanism can be observed in social insect societies. For example, the interaction of ants is based on pheromones only as ants do not communicate directly. Ants put down pheromones in their environment leaving signals to other ants thus influencing their behavior. The main requirements for information sharing in logistics, i.e.:

– sharing information on possible paths and means of transportation locally
– sharing information on the costs and the degree of fulfillment of objectives for different alternatives
– sharing information on preferable clustering of goods in order to allocate a shared resource

can be fulfilled by a stigmertic information storage and updating. In addition, the concept of Stigmergy could provide a solution for logistic scenarios in which the bandwidth for communication between the elements is limited.
A similar approach for shop floor logistics was recently presented in [3]. This proposal of a swarm intelligence approach for manufacturing control is based on the assumption that logistic entities are represented in a centralized computer architecture by agents. For coordination purposes, these agents send out a kind of mobile agent (artificial ants) to lay down information in the environment. Three different types of such artifical ants are used: feasibility ants that track feasible routes, exploring ants for a forward exploration and intention ants that represent preferences of the entity agents. Whereas the concepts are realizable on the shop floor they fail in wide area transportation because they have to map both the biological stigmergic system and the application domain, i.e. the World as Valckenaers et.al. call it, onto a software system that must be able to communicate with the real world items every time. In contrast, we aim to partially distribute the information (pheromones) indeed locally, such that even under temporarily not available communication infrastructure routing decisions can be rendered from locally available stigmergic information. Such a concept of stigmergy was already successfully applied to adaptive telecommunication routing problems where it was implemented in fields of distributed optimization and problem solving [4]. In telecommunications systems artifical ants are sent out in regular time intervals to explore the available transmission lines and to update routing tables in several routing nodes. Here the artificial ants are data packets and in principle their properties and enviroment are the same as for the data packets that have to be routed. This is not necessarily the case in manufacturing or traffic systems, where on the one hand physical materials have to be transported and on the other hand artificial ants can be transmitted through communication lines. In the latter case, communication times are often negligible compared to the processing time, i.e. the transportation time of physical goods. These special properties of logistic systems have to be carefully assessed for design and development of adapted swarm intelligence algorithms for distributed optimization in logistics.

4 Conclusion and Further Research

In this contribution we present an overview of recent developments in application of swarm-intelligence approaches to logistic systems. We argue that for wide area applications where a large number of logistic entities have to be coordinated with limited communication and computational resources the application of swarm intelligence principles may be beneficial. Inherent properties of swarm intelligence like the massive system scalability and the emergent intelligent behavior from local interactions by communication through distributed information in the environment are desirable properties of this bio-inspired approach. However, to realize these promises a careful design of the overall system, including a concept for distribution and updating of stigmertic information is necessary. Thus much work remains to be done. This includes careful estimation of the performance of the herein proposed approaches compared other possible distributed problem solving algorithms for the specific logistics problems.

5 Acknowledgment

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INVITED PAPERS

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Terminology Integration for the Management of distributed Information Resources

Ubbo Visser, Heiner Stuckenschmidt, Christoph Schlieder, Holger Wache, Ingo Timm

1. Introduction

Efficient information management and the processes therein become more and more important within enterprises or when enterprises are merging together. Most information systems use specific data models and databases for this purpose. This implies that making new data available to the system requires, that the data be transferred, into the system's specific data format. This is a process, which is very time consuming and tedious. Data acquisition, automatically or semi-automatically, often makes large-scale investment in technical infrastructure and/or manpower inevitable. These obstacles are some of the reasons behind the concept of information integration.

Problems that might arise due to heterogeneity of the data are already well known within the distributed database systems community (e.g. [Kim and Seo, 1991]). In general, heterogeneity problems can be divided into three categories:

- Syntax (e. g. data format heterogeneity)
- Structure (e. g. homonyms, synonyms or different attributes in database tables)
- Semantic (e. g. intended meaning of terms in a special context or application)

For information management problems on the structural and semantic level with regards to terminologies are important. Terminologies are important because they contain the companies' knowledge. The IT manager is confronted with the task of how to map one terminology to another terminology. Lately, approaches based on formal ontologies have shown that they are promising.

We discuss an ontology-based approach for the solution to this problem. This approach has been developed within the BUSTER (Bremen University Semantic Translator for Enhanced Retrieval) project which addresses the above mentioned categories by providing a common interface to heterogeneous information sources in terms of an intelligent information broker (see www.semantic-translation.com).

2. Ontology-Based Information Integration

In order to achieve semantic interoperability across information system using different terminologies, the *meaning* of the information that is interchanged has to be understood across the systems. Semantic conflicts occur whenever two contexts do not use the same interpretation of the information. The use of ontologies for the explication of implicit and hidden knowledge is a possible approach to overcome the problem of semantic heterogeneity.

In nearly all ontology--based integration approaches ontologies are used for the explicit description of the information source semantics. But there are different ways of how to employ the ontologies. In general, three different directions can be identified: *single ontology approaches, multiple ontologies approaches* and *hybrid approaches*. Figure 1 gives an overview of the three main architectures.

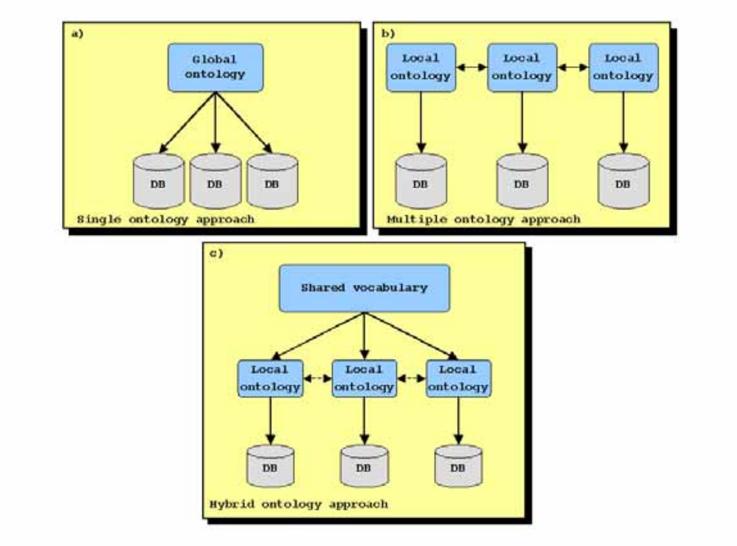

Figure 1: The three possible ways for using ontologies for content explication

- ***Single Ontology approaches:*** Single ontology approaches use one global ontology providing a shared vocabulary for the specification of the semantics (see fig. 1a). All information sources are related to one global ontology. A prominent approach of this kind of ontology integration is SIMS [Arens et al., 1996].
- ***Multiple Ontologies:*** In multiple ontology approaches, each information source is described by its own ontology (fig. 1b). For example, in OBSERVER [Mena et al., 1996] the semantics of an information source is described by a separate ontology.
- ***Hybrid Approaches:*** To overcome the drawbacks of the single or multiple ontology approaches (e.g. finding the minimal ontological commitment), hybrid approaches were developed (fig. 1c). Similar to multiple ontology approaches the semantics of each source is described by its own ontology. But in order to make the source ontologies comparable to each other they are built upon one global shared vocabulary [Goh, 1997]. The shared vocabulary contains basic terms (the primitives) of a domain. In order to build complex terms of a source ontology the primitives are combined by some operators. Sometimes the shared vocabulary is also an ontology [Stuckenschmidt et al., 2000b]. This approach is used within the BUSTER system.

3. Context-based Approach for Terminology Integration

Semantic conflicts occur, whenever two contexts do not use the same interpretation of the information. Goh [1997] identifies three main causes for semantic heterogeneity.

- *Confounding conflicts* occur when information items seem to have the same meaning, but differ in reality, e.g. due to different temporal contexts.
- *Scaling conflicts* occur when different reference systems are used to measure a value. Examples are different currencies or marks.
- *Naming conflicts* occurs when naming schemes of information differ significantly. A frequent phenomenon is the presence of homonyms and synonyms.

It has been argued that semantic heterogeneity can be resolved by transforming information from one context into another (see for example [Sciore et al., 1994]). We investigated two different types of context transformations and their application to the terminology integration problem.

- Rule-based functional transformation [Wache, 1999]
- Classification-based transformation [Stuckenschmidt and Visser, 2000].

We argued that these two kinds of context transformation supplement each other in the sense that functional transformation is well suited to resolve scaling conflicts while classification based transformation can be used to resolve non-trivial naming conflicts [Stuckenschmidt and Wache, 2000].

A conceptual model of the context of each information source builds a basis for integration on the semantic level. We call this process context transformation, because we take the information about the context of the source providing a new context description for that entity within the new information source. Here, we focus on context-transformation by classification. We refer to [Wache, 1999] for further details about the context-transformation with rules.

Context Transformation by Classification

We represent conceptual context with description logic. The idea is to use the inference capabilities of the description logics to derive type transformation rules. The main inference mechanism used in description logics is subsumption checking. A concept is said to subsume another concept, if the membership of the latter implies membership in the former. Following the semantics defined in [Stuckenschmidt and Wache, 2000] the subsumption relation between two concepts is equivalent to a subset relation between the extensions of the concept definition. Subsumption checking can be seen as a special classification method, because it returns a list of classes B_i (concepts) a member of a given concept A belongs to. In terms of subsumption reasoning a context transformation task can be defined as follows:

Let $\boldsymbol{S}$ and $\boldsymbol{T}$ be two terminological contexts represented by sets of concept definitions with subsumption relations $\sqsubseteq_{\boldsymbol{S}}$, $\sqsubseteq_{\boldsymbol{T}}$ and concept membership relations $\in_{\boldsymbol{S}}$, $\in_{\boldsymbol{T}}$. Let further S be a concept from one terminological context $\boldsymbol{S}$ ($S \in \boldsymbol{S}$). Then the transformation of a data set s from context $\boldsymbol{S}$ into the context $\boldsymbol{T}$ is described by $(s \in_{\boldsymbol{S}} S \Rightarrow s \in_{\boldsymbol{T}} T) \Leftrightarrow (S \sqsubseteq_{\boldsymbol{T}} T)$. In general, it is not decidable, whether the condition $(S \sqsubseteq_{\boldsymbol{T}} T)$ holds, because the subsumption relation is only defined for the context $\boldsymbol{T}$ while the concept definition S is taken from context ***S*** and is therefore used by a different subsumption relation. At this point, the shared vocabulary plays an important part. Provided, that the concepts from both contexts are defined using the same basic vocabulary, we get a unified subsumption relation defined as $\sqsubseteq = \sqsubseteq_S \cup \sqsubseteq_T$. We can compute $\sqsubseteq$ using available subsumption reasoner that support the language. The result is a set of elements, which belong to the computed class. We can use these to define a set of new context transformation rules. These rules supplement the rule base for context transformation integrate classification-based and rule-based transformation.

4. Application of Terminology Integration

Both approaches, context transformation with rules and context transformation by classification have been developed and implemented within the BUSTER system. One application of the BUSTER system is the integration of catalogue systems within a geographical domain. We describe how the terminology of one catalogue system can be transformed into a different standard classification.

Catalogue Systems

Geographical information systems normally distinguish different types of spatial objects. Different standards exist specifying these object types. These standards are also called catalogues. Since there is more than one standard, these catalogues compete with each other. To date, no satisfactory solution has been found to integrate these catalogues. In our evaluation we concentrate on different types of areas distinguished by the type of use.

We use two catalogue systems, namely the German ATKIS-OK-1000 [AdV, 1998] and the European CORINE (Co-ordination of Information on the Environment) land cover catalogue [EEA, 1999]. The ATKIS catalogue is an official information system in Germany. It offers several types of objects including definitions of different types of areas. Figure 2 (left) shows the different types of areas defined in the catalogue.

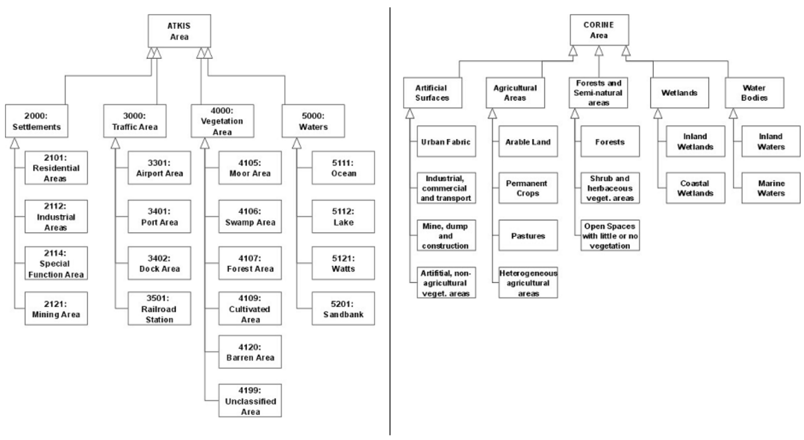

Figure 2: Taxonomy of land-use types in the ATKIS-OK-1000 catalogue (left) and in the CORINE land cover nomenclature

CORINE land cover is a deliverable of the CORINE program the European Commission carried out from 1985 to 1990. The nomenclature as one result developed in the CORINE program can be seen as another catalogue, because it also defines a taxonomy of area types (see figure 2 right) with a description of characteristic properties of the different land types.

The taxonomies of land-use types in figures 2 and 3 illustrate the context problem mentioned in the introduction. The set of land types chosen for these catalogues are biased by their intended use: while the ATKIS catalogue is used to administrate human activities and their impact on land use in terms of buildings and other installations, the focus of the CORINE catalogues is on the state of the environment in terms of vegetation forms. Consequently, the ATKIS catalogue contains fine-grained distinctions between different types of areas used for human activities (i.e. different types of areas used for traffic and transportation) while natural areas are only distinguished very roughly. The CORINE taxonomy on the other hand contains many different kinds of natural areas (i.e. different types of cultivated areas), which are not further distinguished in the ATKIS catalogue. On the other hand, areas used for commerce and traffic is summarized in one type.

Despite these differences in the conception of the catalogues the definition of the land-use types can be reduced to some fundamental properties. We identified six properties used to define the classes in the two catalogues. Beside *size* and *general type of use* (e.g. production, transportation or cultivation) the *kinds of structures* built on top of an area, the *shape of the ground* and *natural vegetation* as well as kinds of *cultivated plants* are discriminating characteristics. Using these properties we performed successful experiments with the identification of forest areas [Visser et al., 2001].

5. Discussion

We have seen that context transformation by re-classification is powerful enough to solve semantic heterogeneity problems within terminological integration tasks. However, we would like to address two issues at this point: (a) modeling effort and (b) domain independency.

One might argue that the amount of time spending on the modeling task in order to get a proper ontology is too much. In section 4 we have seen that our approach can be used to solve the terminological integration task of the ATKIS/CORINE scenario. The amount of time that we invested in the ontology-modeling task was acceptable.

The proposed context transformation approach should be generic enough to solve problems within different domains. We successfully applied our approach to a second application area (supply chain management) and conclude that the approach is domain independent. This domain independency is important to note and one of the key issues of our approach.

The discussed approaches are developed to support both the retrieval and integration of distributed and heterogeneous data based on thematic relevance criteria. However, thematic relevance is not the only criteria, often data objects refer to some kind of geographical space. Gazetteers can be used for spatial reasoning. In [Schlieder et al., 2001] we have shown that existing gazetteer approaches are not sophisticated enough to serve the users queries and presented a new geographic footprint based on connection graphs. Our newest ideas point to the integration of terminological and spatial reasoning.

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The *Agent.Enterprise* Multi-Multi-Agent System

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Abstract: This paper presents the development of the Agent.Enterprise system, which consists of five multi-agent systems from the manufacturing logistics domain. Consequently, the development process has to take the distributed structure of the involved projects into account. The maturity of the technical foundations for multi-agent systems and the support by development tools, infrastructure services and development methods leads to an increasing number of existing multi-agent systems and entails the need to couple them into large multi-multi-agent systems. The Agent.Enterprise development process combines aspects from established agent-oriented development with new concepts designed to interlink multi-agent systems. The structure of the coupled multi-agent systems is designed to inherently meet the requirements of distributed supply chains where information for integrated production planning and control is not available within the whole supply chain. This functionality is an integral part of the Agent.Enterprise System. As a consequence, the system is able to handle severe disturbances at supplier sites while dealing with highly customized and complex products.

Keywords: Multi-agent systems, Agent-oriented software engineering, Distributed planning

1 Introduction

Multi-agent systems (MAS) perfectly suit the demands for global flexibility, co-operation and at the same time local autonomy. Compared to existing SCM systems, the successful integration of numerous MAS that perform both inter- and intra-organizational planning and execution tasks is an innovation, which could lead to an improvement in the design of SCM systems.

The technical foundation for the development of large multi-multi-agent systems (MMAS) is provided by the growing success of the FIPA-standard [FIPA] for MAS and its compliant frameworks, e.g. JADE [BPR01], and the availability of an open service infrastructure, such as Agentcities [Agentcities]. Unfortunately, there is no guidance on how such systems should be built, since the existing agent-oriented development methods are focused on isolated MAS. Therefore, we present an approach for building MMAS that originate from the German priority research program 1083 “Intelligent Agents in Real-World Business Applications” where five projects from the manufacturing logistics domain integrate their MAS prototypes in one large MMAS called *Agent.Enterprise* [Frey03b].

*Outline***.** Our *Agent.Enterprise* approach is presented in Section 2 together with the application domain and the Gateway-Agent Concept, which sets up some basic conditions for the approach. In Section 3 we show some characteristics of the resulting prototype. Finally, Section 4 draws some conclusions.

2 The *Agent.Enterprise* Approach

The *Agent.Enterprise* initiative is a platform which has as its goal to integrate recent research results and join forces in order to build up a networked, agent-based application scenario for the manufacturing domain [Frey03b]. In order to address the difficulties caused by the distributed structure of the involved projects, we developed a concept based on well-known methodologies of agent-oriented software engineering.

Over the last years, the need for applicable and broadly accepted development methods for multi-agent systems resulted in a large number of efforts undertaken to overcome this problem. Various methods exist, which support at least one of the established development phases (analysis, design, implementation, and deployment) with representations of varying formal accuracy and semantic foundations, e.g. Gaia [WJK00], PASSI [CP02], MASSIVE [Lind01], MaSE [WD01], AUML [OVB01].

The majority of the mentioned methods focuses exclusively on building a single (most often closed) MAS and thus, does not consider the development or integration of MMAS. Nevertheless, it can be expected, that the development process for MAS and MMAS will have some joint properties. The following subsections outline how we developed the *Agent.Enterprise* MMAS and present some underlying design decisions. (For a more detailed discussion of our approach and a comparison to some of the mentioned methods see [Sto04].)

2.1 The Development of *Agent.Enterprise*

Unlike GAIA, PASSI, MASSIVE and other agent-oriented development methods the *Agent.Enterprise* concept focuses on a distributed and weakly coupled development process, while minimizing the time required for face-to-face communication. Consequently, the initial design period is comparatively short and restricted to the constitution of the speech acts and the interaction protocol design.

The results of the analysis and design process are consolidated in functionally restricted prototypes, which constitute a test bed for the components of the evolving MMAS. The projects substitute their prototypes with gateway-agents in order to connect their applications to the common scenario. This requires a process of repeated cycles of redesign, implementation, and tests. Figure 2.1 depicts our development approach, while a detailed description can be found in the following subsections.

Role Definition and Assignment

The focus of the related research was taken as the major criterion to assign a specific functionality within the supply chain to the various participating projects. The roles assumed by a project will now be assigned in respect to its functionality. Yet, the next step is to bring life to the roles.

Use Case Specification

A first approximation of the use case specification is made by a simple role-playing technique. One member of the scientific staff of each participating projects takes over the role of her MAS and writes down its informational requirements. Following this, cards are handed out. The sender writes down the contents of the message as well as the receiver, therefore each card represents a single act of communication. Starting with the initiator of an order, in other words the customer, the whole supply chain is acted out until finally the last card announces the delivery of the order from the OEM to the customer. As a result of this role-playing technique, the communication acts between the projects' MAS as well as the required information are specified informally and have to be formalized.

Speech Act Design

After defining the roles for each participating MAS, it is necessary to ensure that high-level communication between the systems is possible. However, a language barrier for the communication exists due to the heterogeneity of knowledge representation and semantics in the individual systems. Consequently, we introduce the so-called Gateway-Agent Concept, which is outlined in the next subsection. This concept defines a virtual MAS where the agents are scattered across a number of agent platforms such that an ontology can specify the semantics of the conversations. While using ontological expressions as a means of communication, we chose to agree on a shared ontology for the communication between the gateway-agents, while future work may include semantic mediation based on a common terminology.

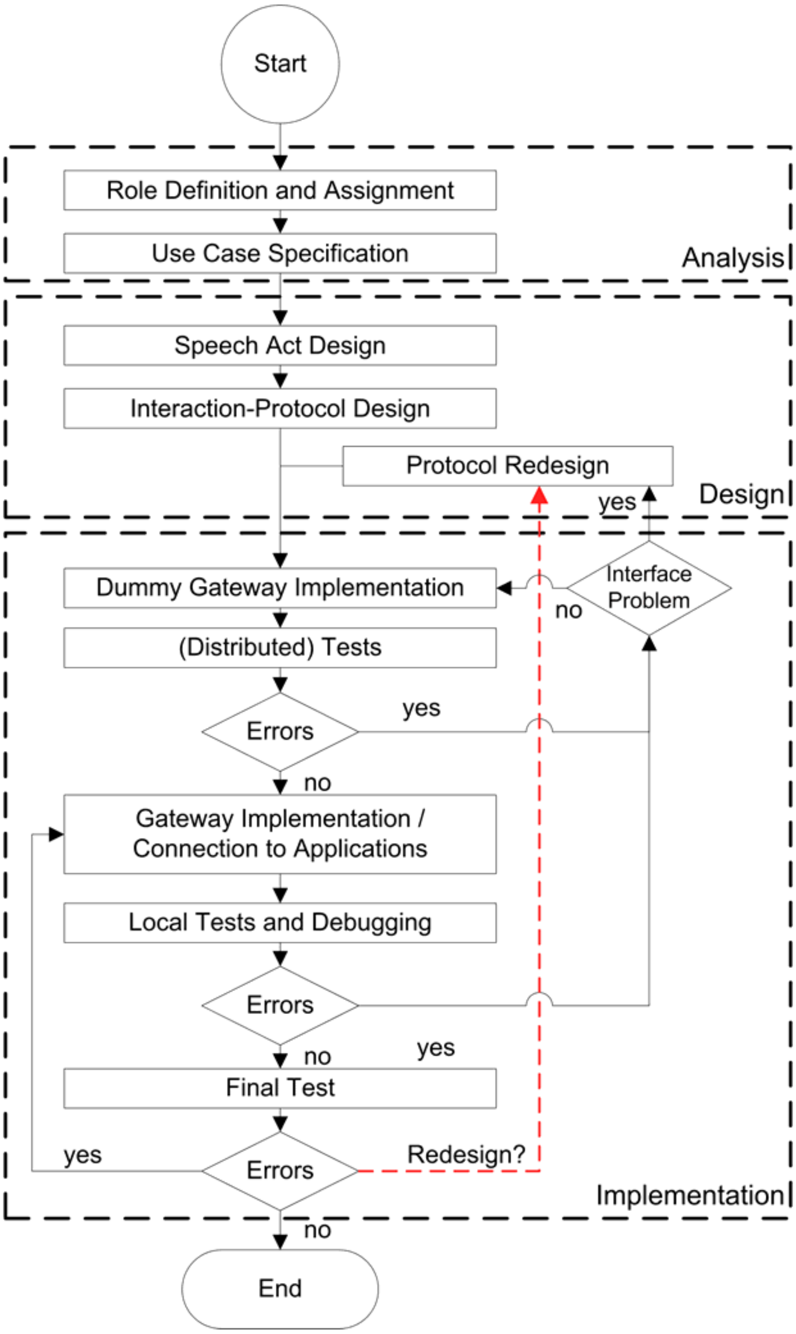

Fig. 2.1. The *Agent.Enterprise* development process

The task of ontological modeling is performed using the method described in [NM01], which was supported by an ontology modeling tool. There is a number of tools, which support ontology-modeling, ranging from Protégé [Gen02], OilEd [Bech01] to WebOnto [Do98], of which Protégé proved to be the best suited for the task of ontology modeling in a multi-agent environment. The Protégé-plug-in Beangenerator [Aart02] offers the functionality to generate code for the modeled ontology that is applicable with the JADE agent platform, which is used in several projects as development framework.

A starting point for the ontology modeling is to identify the actions of the agents, which are requested from their communication partner. They are directly derived from the assigned functionalities and specify which tasks are to be performed. At this point, the ontological concepts defining the artifacts to be dealt with in the agent actions can be specified, like e.g. the products to be manufactured. After modeling all the details for the supply chain, the concepts required for the supervision of all participating MAS are designed.

Interaction Protocol Design

The next step in the overall design process is to define the dynamics of the conversations, i.e. which interaction protocols will be used for communication. The informal specification of interactions resulting from the card role-play is mapped to corresponding FIPA interaction protocols. As a result, the behavior of each gateway-agent for each MAS is specified as far as communication between the gateways is concerned. The final step of the coupling process is to realize communication between the gateway-agent and the underlying MAS.

(Distributed) Implementation

Based on the distributed structure of our research program, the development process takes into account long periods of independent development. Inspired by the concepts of Extreme Programming [Beck99], the process starts with the implementation of functionally restricted prototypes executing a simplified test case. These prototypes serve two purposes. On the one hand a consolidation of speech acts and interaction protocols is enforced. On the other hand, a test bed for autonomous development emerges. The implementation of these prototypes is closely bound to test-sessions and frequently requires a redesign of the speech acts and/or interaction protocols. The outcome of this work is a set of test modules and an exchange of experience within the covering research program. A simplification of the central projects' functions in the 'Dummy Gateway Implementation Cycle' could prove to be a downside of our approach. This fact might result in a setting where some aspects of the interaction protocols could not be sufficiently tested.

Subsequent to the completion of the prototypes, each project integrates its fully functional application into the test bed. Sometimes a project has to debug prototypes of other projects. Explicit phases for consolidation are not necessary due to the strictly defined responsibilities for each prototype.

2.2 The Gateway-Agent Concept

Integration of complex systems requires agreements of architectural and technical nature in order to avoid a time-consuming struggle with implementation details. For *Agent.Enterprise* two central design decisions are subsumed in the so-called Gateway-Agent Concept. This is illustrated in Figure 2.2.

Firstly, the agreement upon the use of FIPA-compliant platforms avoids many of the communication-related obstacles and allows for concentrating on domain aspects. The second decision is that every individual MAS to be integrated should be represented by a single agent, that comprises all roles of its corresponding MAS, and provides them to the resulting MMAS.

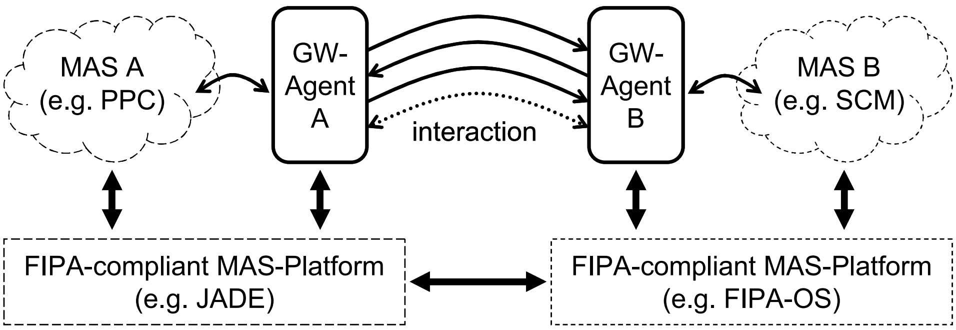

Fig. 2.2. The Gateway-Agent Concept

Thus, the interacting gateway-agents build up a virtual MAS. Together, these decisions can be seen as a specific MMAS architecture, which subsumes aspects of various well-known software patterns [Gam95].

- Façade pattern: The gateway-agents provide a unified interface to their MAS as a subsystem, comprising different roles and their respective functionality.
- Wrapper pattern (called Adaptor in [Gam95]): The gateway agents translate between internal formats and behavior of their corresponding MAS and the common representation in the virtual MAS.
- Bridge pattern: The different types of the gateway agents provide abstract interfaces decoupled from the implementation of their MAS. In the next section we give an example of three MAS that play the role of a supplier in a supply chain scenario. In the virtual MAS they all are represented by the same type of gateway agent while their implementation is completely different and independent.

There are many advantages of the Gateway-Agent Concept, e.g., only the gateway-agents must be available and externally visible for the other MAS during operation. In the earlier implementation phases developers can put their effort on the gateway-agent, when debugging the interoperability between the different MAS. Also, there is no restriction in the centralization of different roles of a MAS into a single gateway-agent. This is due to the fact that different functionalities of this agent can be redirected to several other agents in the MAS, which are represented by the gateway-agent.

3 The *Agent.Enterprise* System

The *Agent.Enterprise* System is the result of successfully applying the presented concept in the manufacturing domain. In the following subsection the MMAS is detailed to better understand the benefits of coupling MAS.

3.1 Scenario

The complexity of managing supply chains results in many different interdependent tasks such as planning, executing and controlling of production, transportation and warehousing processes. As a consequence, different MAS specializing on certain tasks have to interact with each other. The basic scenario focuses on production processes, whereas aspects of transportation can be integrated. Table 3.1 provides an overview of the various functionalities of the involved MAS.

Main Functionality	**Project/MAS**
Negotiations between enterprises	DISPOWEB
Integrated process planning and scheduling (with focus on discrete manufacturing)	IntaPS
Production planning and controlling (with focus on assembling industries)	KRASH
Production planning and controlling (with focus on batch production)	FABMAS
Operational tracking of orders including suborders in supply chains	ATT*
Analysis of historical tracking information (tracing)	SCC*

* ATT and SCC conducted in one project [ATT/SCC]

Table 3.1. Overview of individual MAS functionalities

A typical supply chain management cycle of distributed global planning as a part of the supply chain activities is shown in Figure 3.1. After generating an initial plan of orders and suborders comprising prices and points in time of delivery, software agents located at the different supply chain partners carry on negotiations. Thereby, they optimize the costs and the due delivery dates (see Figure 3.1, ①).

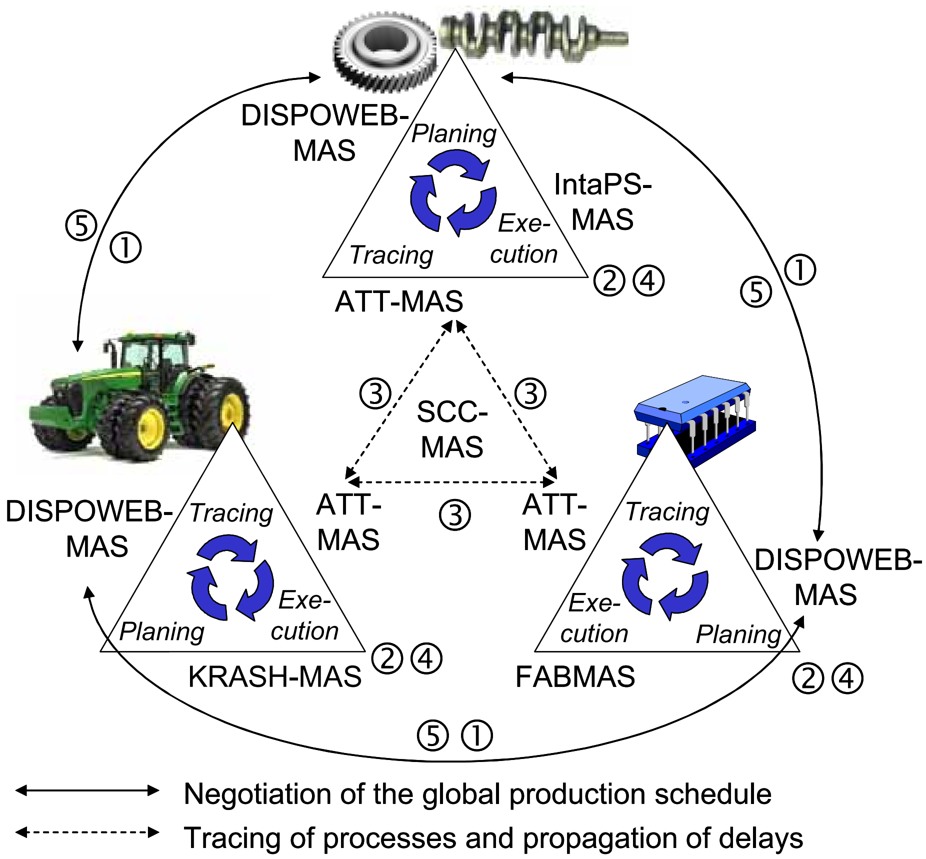

Fig. 3.1. MAS interaction in the integrated SCM architecture

These optimized delivery plans are used on the intra-organizational level to coordinate the production of goods on each stage of the supply chain in detail. Three different MAS [FABMAS] [KRASH] [IntaPS] are concerned with varying aspects of production planning (②). They require the input from DISPOWEB agents and generate detailed plans for their production facilities [DISPOWEB].

These plans are the initial input for a controlling system, which is developed in the ATT/SCC project. This MAS monitors orders on every stage of the supply chain using a distributed architecture in order to proactively detect events that endanger the planned fulfillment. In case of such an event, e.g. a disruption in a production cycle, the ATT system informs the related partner enterprises about the event (③). This information can be used to trigger the re-scheduling of plans on an enterprise level (④) or, in case of major events, even in the re-negotiation of contracts on the inter-enterprise level of the DISPOWEB system (⑤). An overview of activities and corresponding actors in the supply chain are given in Table 3.2.

Nr.	Activity (Actor)
①	Negotiate initial plan of production between supply chain partners (DISPOWEB).
②	Operational assembly planning (KRASH). Production planning for e.g. mechanical parts (IntaPS). Production planning for e.g. electronic parts (FABMAS).
③	Monitoring of orders and related suborders (ATT). Trigger internal planning systems in case of minor critical events (ATT). Next → ④ Trigger re-planning by DISPOWEB agents in case of a severe critical event (ATT). Next → ⑤ Controlling information is forwarded to trusted third party SCC-system (ATT/SCC).
④	Internal rescheduling in reaction to a critical event (KRASH, IntaPS, FABMAS). Next → ③
⑤	Renegotiate plan of production between supply chain partners due to severe critical event (DISPOWEB). Next → ②

Table 3.2. Activities and actors

In addition to the operational monitoring of orders, the ATT system communicates results of negotiations to a trusted-third-party service called the SCC-MAS. This agent system analyzes the history of orders and their related sub-orders. SCC is able to identify patterns in the supply chain and order types that typically lead to problems during fulfillment. This information is used as an input to enhance the tracking functionality of the ATT systems, as well as an input for the DISPOWEB agents to enhance their negotiation strategies, e.g. charging lower prices from suppliers with bad performance.

3.2 Benchmarking

Manufacturing systems have to provide flexibility and robustness to stay competitive. Multi-agent systems are expected to be more flexible than monolithic systems. In addition, special mechanisms integrated into the SCM reference model ensure the reliability of the MAS. Three features assert the flexibility and reliability of the supply chain.

1. Flexibility of the SCM is achieved by a distributed structure of optimization algorithms.
2. Proactive tracking and tracing methods are integrated into the reference model.
3. The distributed local shop floor PPC algorithms must be robust.

The first and the second feature have been discussed in the preceding subsection (3.1). The robustness of the shop floor planning systems is the basis for higher-level reliability of the SCM system.

On this intra-organizational level KRASH, IntaPS and FABMAS offer MAS-based PPC functionality. In the scope of the presented supply chain reference model, the shop floor MAS architectures match the requirements defined above. The statement that MAS are more flexible and robust than traditional planning systems can be verified using realistic benchmarking scenarios. The throughput times of productions orders were analyzed, whereas both the medium throughput time and its standard deviation were checked. The planning process was performed by a reactive MAS approach on one hand and a common OR algorithm on the other hand.

The evaluation shows, that the suitability of the PPC MAS depends on the frequency of disturbances. Nevertheless the standard deviation for the MAS was permanently lower throughout the whole evaluation process. Figure 3.2 shows a scaled comparison factor representing the probability of the MAS, respectively the OR algorithm to perform better. Values larger than 0 represent scenarios where the MAS is superior to the OR approach. It is obvious that this statement is valid for this example. The results even improve when the planning complexity of the scenario is increased (equals a decreasing lot size in this example). For further information concerning the OR algorithm and the evaluation process refer to [Frey03a].

Constant (or nearly constant with at least a small standard deviation) and thus predictable throughput times are a prerequisite for high quality results of the DISPOWEB planning MAS. Along with the ATT-MAS, this robustness on the operational level takes care of the overall robustness of the integrated SCM architecture.

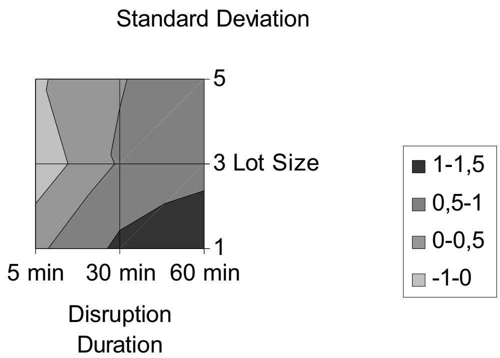

Figure 3.2. Suitability of a MAS approach with respect to the standard deviation of the throughput time

A potential disadvantage of the architecture is the increased communication and co-operation effort. This question has to be investigated in the next phase of the priority research program by testing the implemented MAS using realistic test case scenarios. One instantiation of a benchmark scenario is available at http://www.is-frankfurt.de/tractor. The chosen supply chain represents a tractor manufacturer and its suppliers. The transfer of the results to a broad spectrum of applications is possible due to the closeness of the test case to the automotive industry.

4 Conclusion

This paper presents our approach to couple MAS by combining and applying aspects from well-known agent-oriented development methods. Consequently, it accounts for the special needs that arise from the nature of MAS integration and the technical system architecture agreements. Moreover, its design fits the needs for distributed development.

The existence of sufficiently specified concepts does not require additional conceptual effort since these concepts are applicable for most steps in our proposed development process. Nevertheless, the introduced technical concept, called Gateway-Agents, accelerates the implementation by forcing necessary agreements on technical standards. The concept is presented in this paper as an integral part of the *Agent.Enterprise* development.

The resulting MMAS covers services in the range of supply chain scheduling, shop floor production planning and control, and proactive tracking and tracing services and represents a large-scale adaptable research prototype that guarantees the reliability of overall supply chain processes. The reference architecture and its interfaces and gateways are tested on the basis of a test case scenario. The goal of the evaluation is to prove the feasibility of the approach and gather first insights and results.

The objective of the participating projects in the *Agent.Enterprise* initiative is the enhancement of the existing work to a demonstration and evaluation platform, which supports the presentation and benchmarking of the subprojects.

Acknowledgements

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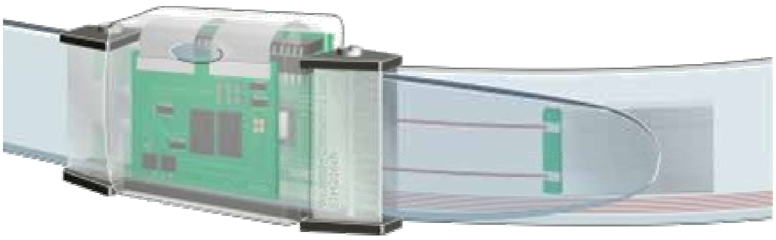
wearIT@work
Empowering the mobile worker by wearable computing

Background

wearIT@work was set up by the European Commission as an Integrated Project to investigate "Wearable Computing" as a technology dealing with **computer systems integrated in clothing**.

The project has 36 partners, among them EADS, HP, Microsoft, SAP, Sony, Siemens, and Zeiss.
With a project volume of about 23.7 million € and a funding of about 14.6 million € under contract no. 004216, ***wearIT@work*** is the largest project worldwide in wearable computing. The **TZI** is one of the University of Bremen research centres and coordinates this key project of the "Bremen Mobile Research Centre". - ***wearIT@work*** contributes to the shaping of today's most challenging computer applications.

Project Description



wearIT@work will prove the applicability of computer systems integrated to clothes, the so-called wearables, in various industrial environments.
These novel computer systems will support their users or groups of users in an unobtrusive way wearing them as a computer-belt. This will allow them to perform their primary task without distracting their attention enabling computer applications in novel fields.

Interaction with wearables by the user must be minimal to realize optimal system behaviour. For this reason a wearable computer recognizes by integrated sensors the current work progress of a user.
Based on the work context detected the system pushes useful information to its user, e.g. how to proceed with the work. Apart from speech output, media could be optical systems presenting the information, e.g. via semitransparent glasses within the workers visual field. Output devices for tactile feedback will be applicable, too.

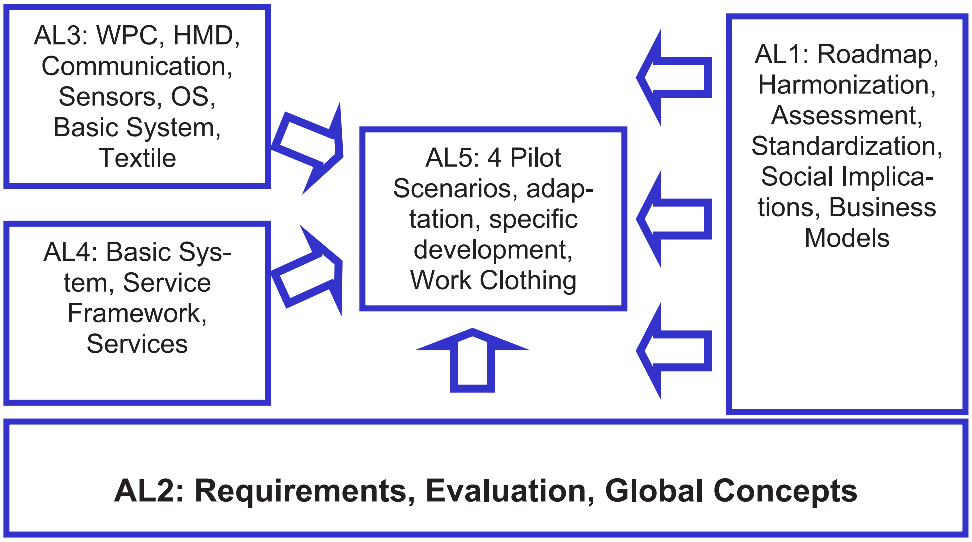
Project Goals

One of the major goals is to investigate the **user acceptance** of wearables. Furthermore methods for user interaction and processes suited to wearables in industry will be identified. It seems to be essential to have methods to detect the work context and have a general architecture of wearables as well as a hardware and software platform for the implementation of wearables. This will be the basis for the four industrial pilot applications, variant production, the clinical pathway, maintenance and emergency.
In **variant production** the challenge will be the information integration and the intelligent information presentation. For **the clinical pathway** the focus will be on intelligent information logistics and context aware collaboration. The **maintenance** scenario will have its focal point on context detection and intel-

ligent manuals. The focus of the **emergency** activity field will be the collaborative planning and interaction using wearable devices.

Project Aspects and Organisation

This Integrated Project is organised in activity lines (AL) and activity fields (AF) to manage its complex structure and follows a **human centred approach**. The pilot applications will be developed in a 1 ½ year's cyclic manner based on the subsequent project structure.



Advantages

The following advantages are expected: First of all an improved productivity and flexibility of workers shall be reached. Second an increased safety at work and a decreased pressure towards automation is aimed. All this will allow a simplified access to enterprise information and lead to faster group decisions. Furthermore new information technology products will be introduced into the market based on the pilot applications developed within ***wearIT@work***.

The worldwide market for wearable computers generated over $70 million in supplier revenues in 2001. The market will increase at a compound annual growth rate (CAGR) of over 51% through 2006, and grow to over $563 million.

Despite its massive growth, the market for wearables is still a niche market compared to the industrial use of desktop computers. Drivers of a stronger growth will be more standardised hardware and software platforms enabling the new work paradigms. ***wearIT@work*** intends to be with its partners a key driver for this market.

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